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Associations between Depression and Blood Pressure among United States Adults: A Bayesian vs. Frequentist Approach

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ASSOCIATIONS BETWEEN DEPRESSION AND BLOOD PRESSURE AMONG UNITED STATES ADULTS: A BAYESIAN VS. FREQUENTIST APPROACH

by

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APPROVAL PAGE

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Author’s Statement Page

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Abstract

High blood pressure can lead to life threatening incidents such as a heart attack or stroke. The direct costs of high blood pressure are expected to rise to 154 billion dollars annually by 2035. Depression is one of the most prevalent mental illnesses in the United States with an estimated 35% of those who experienced major depressive episodes not receiving treatment. The research question this study aims to answer is if there is an association between depression and blood pressure. This study also aims to see if results are comparable between models using frequentist statistics and Bayesian models using weakly informative priors and informative priors. To assess the association, linear regressions of crude and adjusted associations between depression and systolic/diastolic blood pressure were run. The same models were run using Bayesian weakly informative priors and informative priors. Only the model implementing Bayesian informative priors found an association between depression and systolic blood pressure with a mean of 0.119 (95% Confidence Interval: 0.024, 0.216). However, the association was unadjusted. The association between depression and systolic blood pressure is statistically significant, but it lacks clinical significance.

Chapter 1

INTRODUCTION

1.1 Background

Though the length of life is increasing around the world, chronic conditions such as heart disease are becoming the leading cause of death for most countries around the world including the United States. 17.9 million people around the world die from cardiovascular related deaths, which accounts for 31% of all deaths worldwide (World Health Organization, n.d.). In the United States alone heart disease is the leading cause of death among men, women, and most race groups. Each year in the United States 1 in 4 deaths is attributed to heart disease. A common type of heart disease is coronary artery disease, which is prevalent among 18.2 million or 6.7% of adults over the age of 20 in the United States. Outcomes of heart disease can include events such as heart attacks, which occur every 40 seconds in the United States. A common risk factor among those with heart disease is high blood pressure or hypertension (CDC, 2019). Blood pressure is the pressure of blood on the walls of arteries. When blood pressure is consistently high this could lead to hypertension. Not only can high blood pressure increase the risk of heart attack, but it can also increase the risk of stroke or kidney disease (CDC, 2020). In 2015 approximately 96.1 million Americans had high blood pressure. That number was projected to rise by 27.1 million in 2035. In 2015 the medical cost of treating high blood pressure was 68 billion dollars, and by 2035 costs are expected to rise to 154 billion dollars. Not only does high blood pressure pose a cost burden through medical services, but it can also pose a cost burden in the home and workplace through the loss of productivity. These indirect costs can occur through morbidity or premature mortality. In 2015 indirect costs of high blood pressure were 42 billion dollars and that number is expected to rise to 67 billion dollars in 2035 (American Heart Association CVD Burden Report, 2017). Due to the burden in both costs and risk of death, it is important to understand what risk factors contribute to high blood pressure to alleviate the future burden posed.

Depression is described as having changes in moods, cognitive function, and physical function during a two week period. Though depression is treatable, it is a common mental disorder. Along with depression being associated with age, gender, race, income, and certain health behaviors, depression can also have high societal costs. Those with depressive symptoms have reported having difficulty with work, home, or social activities. About 80% of adults with depression reported issues with conducting these daily activities. Not only does it pose a burden to the individual and those around them, but it could also pose a cost burden. With a loss in productivity due to depressive symptoms, untreated depression could incur high indirect costs in the United States (Brody et al., 2019).

1.2 Purpose of Study

The World Health Organization defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization, n.d.). Health is mostly thought of as a physical aspect. The purpose of this study is to see how a state of mental well-being might be associated with physical well-being. With high blood pressure bearing an increasing burden of cost, it is important to identify any factors which may be associated with health outcome. By using the National Health and Nutrition Examination Survey (NHANES), which includes both depression and blood pressure as variables, associations can be assessed to better understand risk factors for high blood pressure. To gain the most accurate measure of effect between the two variables frequentist and Bayesian statistics will be utilized in the analysis.

1.3 Research Questions

The following questions aimed to be answered by the study:

1. Is there an association of depression with systolic blood pressure or diastolic blood pressure?
2. Is there an association of depression with systolic blood pressure or diastolic blood pressure after adjusting for covariates?
3. Does Bayesian statistics provide any benefit in understanding the association between depression and blood pressure?
4. How do weakly informative priors and informative priors compare to results found using traditional frequentist methods?

Chapter 2

REVIEW OF THE LITERATURE

2.1 Depression

One of the most prevalent mental illnesses in the United States is depression. About 17.3 million adults or 7.1 % of adults in the United States have experienced at least one major depressive episode in 2017. A major depressive episode can be defined as an individual experiencing a depressive mood for at least two weeks. This can include concerns such as issues with sleep, eating, or loss of interest in activities. About 35% of adults in the United States that have experienced a major depressive episode did not receive treatment for it (Geraghty et al., 2019). Though there are treatment options available, either through a health professional or medication, major depressive episodes are often left untreated in the United States. Depression poses a burden in the United States, but it can often go undiagnosed. It has also been argued for what symptoms will actually constitute as depression episodes, and where the line should be drawn to differentiate depression from emotional distress (Geraghty et al., 2019). This can be problematic since primary care physicians may not refer patients out to receive the psychiatric care they may need. Feelings of sadness or anguish can develop as a response to an emotional experience such as the death of someone close or job loss. Though grief and depression can have similar signs, it is important to note the differences between the two. During times of grief, there may be sporadic occurrences of sadness with some positive memories throughout. In depression loss of interest or pleasure occurs for most of a two week period. Depression may also have feelings of abhorrence towards oneself, while those with grief or sadness maintain self-worth. Despite the differences between responses from emotional experiences and differences, it is possible for those who experience emotional events to lead to depression. Risk factors for depression include biological risk factors such as brain chemistry or genetics, and environmental factors (American Psychiatric Association, 2017).

There have also been differences in major depression between different gender groups. About twice as many women are diagnosed with major depression compared to men (Leach et al., 2008). In 2017 the prevalence of experiencing a major depressive episode in the past year was 8.7 % among females and 5.3 % among males (National Institute of Mental Health, 2019).In 2017 there was also a higher prevalence of depression among the 18-25 year-old age group at 13.1%, compared to 7.7% in the 26-49 year-old age group and 4.7% in those older than 50 (National Institute of Mental Health, 2019). Other demographics such as racial identity have shown to be a risk factor for depression, since some may face adversity and discrimination during adolescent years. This is especially more evident for black and Hispanics who had experienced more stress in the early years due to lower socioeconomic status (Patil et al., 2018). This could have continued the effects of depression on those groups into adulthood. Depression is also related to obesity. Having either depression or obesity can lead to an increased risk of developing the other. Having these two conditions could lead to greater comorbidities (Milaneschi et al., 2019). A high prevalence of smoking has been found among those that have major depression, or have experienced a major depressive episode. Alcohol use was found to be regularly accompanied along with the high prevalence of smoking among those experiencing depression (Stubbs et al., 2018). Lastly, the odds of having a major depressive episode and illicit drug use were found to be significantly higher compared to those who had no illicit drug use (Choi et al., 2016).

2.2 Depression Severity

Depression should not be treated as a binary categorical effect, but rather a continuous effect with increasing severity of major depression occurring with each unit increase. One way of assessing the severity of depression for an individual is through the Patient Health Questionnaire (PHQ). The PHQ-9 is a nine item questionnaire with each question ranging from a value of 0, for not at all, to a value of 3, for nearly every day. The nine item questionnaire is then summed to give a value ranging from 0 to 27. A patient with a 0 score would have no depression symptoms, while a patient with 27 would have very severe major depression symptoms. The PHQ-9 assessment is used to identify a threshold diagnosis for major depressive disorder. The PHQ-9 questionnaire score has cutoff scores of 5, 10, 15, and 20. The scores represent minimal (0-4), mild (5-9), moderate (10-14), moderately severe (15-19), and severe depression (20-27). To assess the validity of the depression screener, a large sample of 6,000 patients were administered the test during visits to primary care clinics or obstetrics-gynecology clinics. Along with the PHQ-9, patients were also administered a Short-Form General Health Survey assessing sick days, clinic visits, and symptom related difficulty. 580 validation interviews were then conducted by mental health professionals blinded by the PHQ-9 score to assess depression diagnostic status. The PHQ-9 achieved a high sensitivity and specificity of 88% each, confirming the reliability in being used to measure depression severity (Kroenke et al., 2001).

2.3 Blood Pressure

Blood pressure occurs when the heart beats and oxygenated blood is pushed throughout the body through a system of tube shaped blood vessels containing arteries, veins, and capillaries. This allows the oxygenated blood to be received by the tissues and organs needed for an individual to survive. Blood pressure has forces from which the readings are taken from. The first reading, or systolic pressure, occurs when blood is pumped to the arteries from the heart. The second reading, or diastolic pressure, occurs during the rest between two heart beats. Hypertension, or high blood pressure, is prevalent when systolic or diastolic blood pressure readings are consistently high (American Heart Association, 2016).

Up until recent history, the awareness of high blood pressure being a risk for cardiovascular disease was relatively unknown. One of the initial measurable associations between high blood pressure and cardiovascular disease was not reported until 1925 by the Actuarial Society of America. Up until then, high blood pressure was thought to be a naturally occurring phenomenon with an increase in age, that is unable to be controlled for. A major prospective longitudinal cohort study, known as the Framingham Heart Study, was one of the first epidemiological studies to assess the outcome of having a prevalence of hypertension. The study found that men between 45 and 62 years with hypertension were three times more likely to have ischemic heart disease, after more than 6 years of follow up, than men who had normal blood pressure. While women among the same age group were six times more likely to have ischemic heart disease (Rahimi et al., 2015). Ischemic heart disease occurs when the narrowing of the coronary arteries in the heart causes less blood to flow through the heart muscle. This is also known as coronary artery disease or coronary heart disease. The narrowing of arteries is commonly caused by a buildup of plaque, also known as atherosclerosis. The chest pains that occur when an individual has coronary heart disease or uncontrolled hypertension are called angina pectoris. This discomfort occurs when the heart muscle has an inadequate amount of oxygenated blood. When the arteries are completely blocked then heart muscle cells die and myocardial infarction, or a heart attack, will occur (Institute of Medicine (US), 2010). The Multiple Risk Factors Intervention Trial study found that isolated systolic hypertension was associated with coronary heart disease mortality, independent of diastolic blood pressure. Likewise, diastolic blood pressure was found to be associated with the risk of having coronary heart disease or stroke incident independent of systolic blood pressure (Rahimi et al., 2015).

As shown by previous studies, having high blood pressure is associated with the risk of developing heart disease. Though blood pressure steadily increases with age, other modifiable and non-modifiable risk factors that are prevalent can also increase the risk of having high blood pressure (Rahimi et al., 2015). A study was done on the risk factors for hypertension of the Canadian population using the Canadian Health Measures Survey from 2007 to 2015. This allows for a nationally representative sample of the population with comprehensive health measures. The study found that adult men had a prevalence of hypertension nearly 25% higher than women. The leading cause of hypertension among both men and women was being overweight or obese. Being overweight or obese had a prevalence of 24% of all hypertension cases (Leung et al., 2019). The prevalence of being overweight or obese for hypertension cases may show a relationship between body mass index (BMI) and systolic blood pressure or diastolic blood pressure. A non-modifiable risk factor that is associated with cardiovascular disease related deaths is an individual’s race or ethnicity. The mortality rate for cardiovascular deaths is 33% higher in non-Hispanic blacks than in the overall population. Hypertension is a known risk factor and a significant contributor to cardiovascular disease. Non-Hispanic blacks have a significantly higher prevalence of hypertension compared to non-Hispanic whites. Non-Hispanic Asians were revealed to be least likely to be aware of their hypertension, and thus report taking any medications (Balfour et al., 2015). The significant prevalence differences of hypertension between different race groups show the disparities of hypertension between those groups. Thus, systolic blood pressure and diastolic blood pressure may be associated with an individual's race. Another risk factor that may be associated with blood pressure is socioeconomic status. Socioeconomic status is a modifiable risk factor that may pertain to an individual's education or income level. A study done on a sample of 94 married couples found that income level was related to both systolic blood pressure and diastolic blood pressure, while education was only associated with systolic blood pressure (Cundiff et al., 2015). Another modifiable risk factor that was found to be associated with blood pressure is smoking. A study was conducted on American Indians, through the Strong Heart Study, to find risk factors for hypertension and their relation to cardiovascular disease. Unlike most other risk factors for blood pressure or hypertension, smoking was found to be negatively associated with both systolic and diastolic blood pressure. Alcohol consumption, a modifiable risk factor, has found to increase the risk of being hypertensive and increase ambulatory blood pressure (Wang et al., 2006). Lastly another modifiable risk associated with blood pressure is illicit drug use, or the use of cocaine, methamphetamine, or heroin. Mean systolic and diastolic blood pressures were found to be significantly higher in illicit drug users compared to non-illicit drug users. Illicit drug users were defined as ever having used illicit drugs (Akkina et al., 2012).

2.4 Blood Pressure and Depression

A cross-sectional study was done by Rantanen et al. (2018) to find an association between awareness of hypertension and depressive symptoms. The study population was conducted on 2,676 patients from Finland at risk for cardiovascular disease, between the ages of 45 and 70. Depression was modeled as a dichotomous variable using the Beck's Depression Index score of at least 13 to indicate a minimum of mild depression. Hypertension was stratified by 3 categories: normotensives, unaware hypertensives, and aware hypertensives. Aware hypertensives were taking blood pressure medication previously. Unaware hypertensives were subjects not previously taking blood pressure medications, but had a mean systolic blood pressure reading of at least 135mmHg, or a diastolic reading of at least 85mmHg. Normotensives were subjects neither taking blood pressure medication nor had a mean blood pressure reading greater than the specified amount. The study found that depression symptoms and hypertension status (known, unaware, or normotensive) are not independent of each other, and there is an association. The study found that the odds of having depressive symptoms were lower for subjects that were normotensive and unaware of their hypertension compared to those that were aware of their hypertension (Rantanen et al., 2018).

A longitudinal study conducted by Ginty et al. (2013) was done to find an association of depression and a diagnosis of hypertension five years later. Participants were drawn from the Dutch Famine Birth Cohort Study, where they were asked various questions and clinic assessments were done. Among those assessments, participants were measured for anxiety and depression using the Hospital Anxiety and Depression Scale (HADS), a psychiatric test with high validity where higher scores signify greater severity of depression and anxiety. An average of five and half years later 455 participants were asked if they have ever received a diagnosis of hypertension from a physician. Depression as a continuous variable had an odds ratio of 1.19, so for every unit increase in depression severity, the odds of being hypertensive increased by 19%. When depression was categorical the odds ratio was 3.44, so the odds of having depression and being hypertensive are 3.44 times the odds of not having depressive symptoms and being hypertensive. The cutoff for the score HADS assessment was set to at least 8 for having depressive symptoms as a binary variable (Ginty et al., 2013).

A cross sectional study conducted on the inhabitants of Norway by Hildrum et al. (2007) was done to find an association between low blood pressure and depression. Data was collected through the HUNT study, a general health study, consisting of a questionnaire, physical examination, and blood tests. To assess depression, the Hospital Anxiety and Depression Scale was used. Cutoff scores of at least 8 were used to identify the presence of depression. Blood pressure readings were taken by trained nurses and averaged for the study. An association was found for having low blood pressure and depressive symptoms. Using multinomial logistic regression modeling resulted in an odds ratio of 1.19 for 0 to 5 percentile systolic blood pressure, and 1.29 for 0 to 5 percentile diastolic blood pressure compared to a 41 to 60 percentile reference group. Those that have lower systolic or diastolic blood pressure are at higher odds of having depressive symptoms compared to those that had no depressive or anxiety symptoms (Hildrum et al., 2007).

A study conducted by Jin et al. (2019) aimed to find the effect of hypertension on depression symptoms among Chinese inhabitants older than 45 using the China Health and Retirement Longitudinal Study. The sample of the study had 6,273 participants who did not have depression at the baseline of the study. Depression was assessed using a form from the Center for Epidemiologic Studies Depression Scale. Depression scores ranged from 0 to 30, and was measured as a binary variable in the study with those who had scores above 10 were classified as having depressive symptoms. Hypertension was measured as a binary variable with those who reported ever having been diagnosed with hypertension, currently taking blood pressure medication, an average systolic blood pressure of at least 140 mmHg, or an average diastolic blood pressure of at least 90 mmHg, as having hypertension. Cox proportional hazard regression models were used to find the effect of being hypertensive at baseline and developing depressive symptoms. The study resulted in a hazard ratio of 1.12 (95% CI: 1.02 - 1.23) for hypertensive participants to have depressive symptoms. Those who were hypertensive were 1.12 times more likely to be depressive than those who were not hypertensive (Jin et al., 2019).

Most of the current literature has found associations between blood pressure and depression in some way or form. However, in most studies conducted depression was analyzed as a dichotomous binary variable such as studies conducted by Jin et al. (2019) and Hildrum et al. (2007). This can be problematic since depression has levels of severity as seen in the depression screener found in the Patient Health Questionnaire (Kroenke et al., 2001). Blood pressure is also treated as a dichotomous variable in the form of having hypertension or not having hypertension. Blood pressure can be treated as a continuous variable or a multinomial variable categorized as normal, prehypertensive, hypertensive stage 1, or hypertension stage 2 (*Understanding Blood Pressure Readings*, n.d.). A study conducted by Zhang et al. (2019) found no association between blood pressure and depression after both were categorized into three different categories (Zhang et al., 2019). Another study conducted by Roane et al. (2017) found no association between depression and systolic or diastolic blood pressure after using linear regressions for the analysis (Roane et al., 2017).

Chapter 3

METHODS AND PROCEDURES

3.1 Data and Sample

The data used in this study were from the National Health and Nutrition Examination Survey (NHANES). NHANES is used to measure the health and nutrition of inhabitants of the United States. The survey consists of both interview questions and physical examinations. The NHANES program is part of the Nation Center for Health and Statistics which is a part of the Centers for Disease Control and Prevention. Though NHANES started in the 1960s, it became a continuous program in 1999, where a nationally representative sample of about 5,000 participants are taken each year. To gather data health interviews are conducted in participants' home. Health measurements and physical examinations are taken through mobile centers traveling across the country. The data is gathered through a team of physicians, medical and health technicians, and dietary and health interviewers. Much of the staff is bilingual with most speaking both English and Spanish. Transportation is provided to the mobile center if necessary. Study participants also receive compensation and a report of the medical findings. All data collected is kept confidential. Questionnaires and examinations are almost all recorded electronically, removing any potential recording errors and making data more quickly accessible (*NHANES - About the National Health and Nutrition Examination Survey*, 2020).

To best assess the relationship between depression and blood pressure NHANES data from 2013 to 2016 was utilized. NHANES 2015-2016 data was used in the frequentist approach and Bayesian analysis. NHANES 2013-2014 was used to get parameter estimates to be used in the informative prior for Bayesian analysis. NHANES 2015-2016 consisted of a sample size of

9,971 participants. Of those participants, 5,164 participants above the age of 18 completed the depression questionnaire. Those that did not complete the alcohol, smoking, and drug use questionnaire were removed from the sample. Participants who had no measurements for age, body mass index, diastolic blood pressure, and systolic blood pressure were also removed from the sample. Lastly, participants who did no provided a household income amount were removed. The final sample for NHANES 2015-2016 used in the frequentist and Bayesian analysis was 3,787 participants. Full 2 year medical examination center weights were used in the frequentist approach. 15 masked variance pseudo-stratums were used for variance estimations, along with 30 primary sampling units for clusters. The same sampling method was in the NHANES 2013-2014 data set to obtain a final sample size of 4,022 observations to be used in obtaining the parameter estimates for the priors in the Bayesian analysis (*DEMO_I*, n.d.).

3.2 Depression

Depression was measured using the nine-item depression screening instrument , or the Patient Health Questionnaire. Questions pertained to depression symptoms participants have been feeling during the past two weeks prior to when the questionnaire was administered. Reponses used a Likert scale to show frequency of symptoms over the past two weeks. Reponses ranged from a value of 0 to 3 for “not at all,” “several days,” “more than half the days,” and “nearly every day”. Participants who responded “refused” or “don’t know” for any questions were recoded as missing. The values were then summed across for each observation, with missing values counting as 0. A summed depression score for each observation ranged from 0 to 27, with each unit increase representing an increase in severity of depression symptoms. The summed up depression scores were used as the primary independent variable in this analysis (*NHANES 2015-2016*, n.d.-b).

3.3 Blood Pressure

Both systolic and diastolic blood pressure readings for study participants were taken in the mobile examination center. Participants rested quietly in a seated position for five minutes and had their maximum inflation level determined before blood pressure readings were taken. Three consecutive blood pressure readings are taken, with a fourth one taken if one of the readings were incomplete. Participants are excluded from blood pressure readings if any physicality issues on both arms prevent any measurements from being taken such as wounds or being unable to fit the blood pressure cuff. Blood pressure readings were administered through certified physician examiners. Both the systolic and diastolic blood pressure readings were averaged across for each observation to obtain an average systolic blood pressure reading and an average diastolic blood pressure reading. The average systolic and diastolic blood pressure readings were the dependent variables in the analysis (*NHANES 2015-2016*, n.d.-a).

3.4 Covariates

Other variables included in the analysis from NHANES included age, body mass index (BMI), gender, race, income, alcohol use, drug use, and smoking cigarettes. Age was treated as a continuous variable, with all participants being above the age of 18. The average age of participants was 43.25 years old. BMI was calculated by taking the weight in kilograms and divide it by the height in meters squared, which is then rounded to one decimal place. The average BMI in the study was 29.6 kg/m^2. Gender was classified as being either male or female, with 1,835 (49.24%) male participants, and 1,952 (50.76%) female participants. Race was defined as being Hispanic, white, black, Asian, or other. Those who were defined as being Mexican American or other Hispanic were recoded to be Hispanic. Annual household income for participants was recoded into being in either low, middle, or high household income. Participants who were in the low household income category made between $0 and $34,999 annually. Those who were in the middle made between $35,000 and $74,999, and participants in the high income category made more than $75,000 annually. Alcohol use was defined as a binary categorical variable of having at least 12 alcoholic drinks in one year. One alcoholic drink includes a 12 ounce beer, a 5 ounce glass of wine, or one and a half announces of liquor. Those who answered “refused” or “don’t know” were recategorized as missing (*ALQ_I*, n.d.). Drug use was defined as a binary categorical variable with participants being asked if they have ever used cocaine, crack cocaine, heroin, or methamphetamine. Those who answered “refused” or “don’t know” were categorized as missing (*DUQ_I*, n.d.). Lastly, smoking was defined as a binary categorical variable with participants being asked if they have ever smoked at least 100 cigarettes in their life. Respondents who answered “refused” or “don’t know” were categorized as missing (*NHANES 2015-2016*, n.d.-c). The frequency distributions for categorical variables and means for continuous variables of the NHANES 2015-2016 sample are displayed in **Table 1**. The frequency percentages are from the weighted frequencies since weights were applied to the sampling distributions. **Table 2** displays each covariates association with the primary independent variable- depression, and the two dependent variables- systolic and diastolic blood pressure. Age, BMI, gender, race, alcohol use, and cigarette use were found to have a statistically significant association with systolic blood pressure at an alpha level of .10. Age, BMI, gender, race, income, alcohol use, and drug use were found to have a statistically significant association with diastolic blood pressure. BMI, gender, race, income, alcohol use, drug use, and cigarette use were found to have a statistically significant association with depression. **Figure 1** displays the associations between depression and blood pressure controlling for covariates determined by the bivariate analysis and literature review.

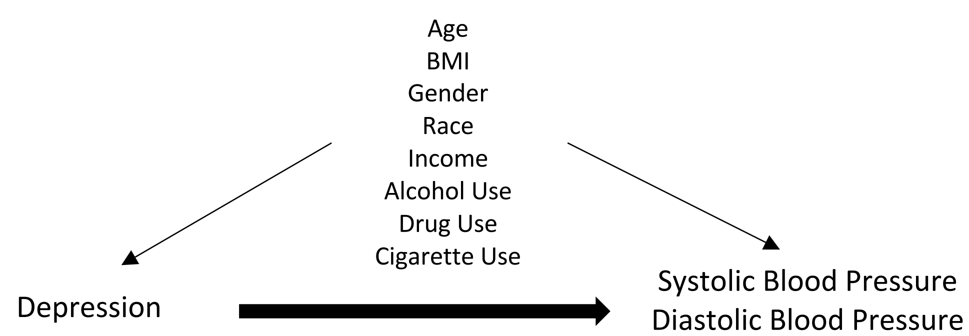
Table 1. Characteristics of NHANES 2015-2016 (n=3787)	
Systolic Blood Pressure, mean (SE)	121.349 (0.414)
Diastolic Blood Pressure, mean (SE)	70.914 (0.504)
Depression, mean (SE)	3.177 (0.127)
Age, mean (SE)	43.246 (0.481)
Body Mass Index, mean (SE)	29.567 (0.271)
Gender, Frequency (%)	
▪ Male	1835 (49.24%)
▪ Female	1952 (50.76%)
Race, Frequency (%)	
▪ White	1194 (64.74%)
▪ Black	835 (11.25%)
▪ Hispanic	1209 (15.56%)
▪ Asian	369 (4.76%)
▪ Other	153 (3.69%)
Income, Frequency (%)	
▪ Low	1408 (25.23%)
▪ Middle	1246 (32.16%)
▪ High	1133 (42.61%)
At least 12 alcoholic drinks a year, Frequency (%)	
▪ Yes	2635 (77.46%)
▪ No	1152 (22.54%)
Ever used cocaine, heroin, methamphetamine, Frequency (%)	
▪ Yes	622 (19.91%)
▪ No	3165 (80.09%)
Have smoked at least 100 cigarettes, Frequency (%)	
▪ Yes	1526 (42.68%)
▪ No	2261 (57.32%)
Percentages are for weighted frequency	

Table 2. Covariate Crude Associations with Systolic BP, Diastolic BP, and Depression

Variable	Systolic BP	Diastolic BP	Depression
Age	<.0001*	0.0001*	0.8102
Body Mass Index	<.0001*	0.0006*	0.0061*
Gender	<.0001*	<.0001*	0.0001*
Race	<.0001*	0.0017*	0.0004*
Income	0.1814	0.0140*	<.0001*
Alcohol Use	0.0745*	0.0933*	0.0006*
Drug Use	0.1635	0.0602*	0.0016*
Cigarette Use	0.0003*	0.3927	<.0001*

- P-values obtained using the survey reg procedure in SAS 9.4
- * indicates statistical significance at an alpha level of .10

Figure 1. Relationship between Depression and Blood Pressure with covariates



- Depression is the primary independent variable, with the dependent variables being systolic and diastolic BP.

3.5 Statistical Analysis

To assess if there is an association between blood pressure and depression from a frequentist perspective, a series of linear regression analysis were run using NHANES 2015-2016. Average systolic blood pressure was one continuous outcome, and average systolic blood pressure was another. A simple linear regression for each outcome was run, with the primary independent variable being the summed up depression score variable. Then multiple linear regressions were run with the models taking into account the covariates age, body mass index (BMI), gender, race, income, alcohol use, drug use, and smoking cigarettes. Since NHANES is a survey data set weight, cluster, and stratum variables were used in the statistical analysis procedures. Models are used to get crude and adjusted parameter estimates for the association of depression on both systolic and diastolic blood pressure. Statistical Analysis System (SAS) software 9.4 was used to run the linear regressions for the frequentist approach, and to obtain distributions and means for the variables used. *Proc surveyreg* procedures were used to run simple linear regressions and multiple linear regressions. *Proc surveyfreq* and *proc surveymeans* were used to find frequency distributions and other characteristics of the sample.

To assess the association between blood pressure and depression from a Bayesian perspective, priors needed to be established. Similarly to the frequentist approach, simple linear regressions and multiple linear regression were run to assess the association between systolic blood pressure and diastolic blood pressure using NHANES 2015-2016. First, weakly informative priors were used for each parameter, including the intercept. The weakly informative prior had a normal distribution with a mean of 0 and a variance of 10,000. The prior mean and variance were used for all parameters in both the simple and multiple linear regression. The model variance was specified as an inverse gamma prior with a shape of .01 and a scale of .01 for all Bayesian models. The posterior distribution is estimated using Markov chain Monte Carlo (MCMC) methods. All model parameters were updated using the Gibb sampling method. When informative priors were used, all parameters were placed in separate blocks to perform Gibbs sampling. The MCMC was set to 22,500 iterations, with 2,500 of those iterations used to burn-in. The MCMC sample size to estimate the posterior mean and variance was 20,000 with one chain done. STATA 16 was used to implement Bayesian analysis and run the linear regressions. A random number seed was established for all Bayesian regression models to have reproducible results.

To assess the associations between blood pressure and depression using informative priors, parameter estimates must be available to create prior distributions. To obtain informative priors, NHANES 2013-2014 data was utilized using the same frequentist approach method done on NHANES 2015-2016. Simple linear regressions and multiple linear regressions were run to obtain mean and variances to be used in the normal distribution priors for the Bayesian analysis. The posterior distribution was then estimated using an MCMC of 22,500 iterations, with 2,500 of those iterations used as a burn-in. The same random seed number was applied to all Bayesian regression model to procure reproducible results.

Chapter 4

RESULTS

4.1 Associations between Depression and Blood Pressure using Frequentist Statistics

Statistical analysis from frequentist statistics methods was done using simple linear regressions and multiple linear regressions. Systolic and diastolic blood pressure were modeled separately. **Table 3** displays systolic blood pressure as the dependent variable and depression as the independent variable. **Table 4** displays diastolic blood pressure as the dependent variable and depression as the independent variable. **Table 5** shows the relationship between systolic blood pressure as the outcome and depression as the independent variable adjusted for the covariates age, BMI, gender, race, income, alcohol use, drug use, and cigarette use. **Table 6** shows the relationship between diastolic blood pressure as the outcome and depression as the independent variable adjusted for the covariates age, BMI, gender, race, income, alcohol use, drug use, and cigarette use.

Table 3. Crude Association between Depression and Systolic Blood Pressure

Parameter	Estimate	Std. Error	t-value	p-value	95% Confidence Interval	
Constant	121.267	0.464	261.450	<.0001	120.279	122.256
Depression	0.026	0.074	0.350	0.733	-0.132	0.184
Model Fit: R^2= 0.000047, F-Value = .12, p-value = 0.7332						

Table 3. The model found an insignificant p-value of 0.733 at an alpha level of .05 for the crude association between depression and systolic blood pressure. The parameter estimate for depression was 0.026 (95% Confidence Interval: -0.132, 0.184). For every one unit increase in depression score, systolic blood pressure increased by 0.026 mmHg. The R^2 value showing the proportion of dependent variance explained by the model was 0.000047.

Table 4. Crude Association between Depression and Diastolic Blood Pressure						
Parameter	Estimate	Std. Error	t-value	p-value	95% Confidence Interval	
Constant	70.939	0.579	122.460	<.0001	69.704	72.173
Depression	-0.008	0.057	-0.140	0.893	-0.129	0.114
Model Fit: R^2= 8.271E-6, F-Value = .02, p-value = 0.8933						

Table 4. The model found an insignificant p-value of 0.8933 at an alpha level of .05 for the crude association between depression and diastolic blood pressure. The parameter estimate for depression was -0.008 (95% Confidence Interval: -0.129, 0.114). For every one unit increase in depression score, diastolic blood pressure decreased by 0.008 mmHg. The R^2 value showing the proportion of dependent variance explained by the model was 8.271E-6.

Table 5. Adjusted Association between Depression and Systolic Blood Pressure						
Parameter	Estimate	Std. Error	t-value	p-value	95% Confidence Interval	
Constant	88.347	1.817	48.640	<.0001*	84.475	92.219
Depression	-0.036	0.068	-0.530	0.602	-0.181	0.109
Age	0.318	0.022	14.600	<.0001*	0.272	0.365
BMI	0.493	0.051	9.670	<.0001*	0.384	0.602
Gender [A]: Male	5.382	0.728	7.400	<.0001*	3.831	6.932
Race [A]: Asian	1.246	0.861	1.450	0.169	-0.590	3.082
Race: Black	5.328	0.834	6.390	<.0001*	3.550	7.106
Race: Hispanic	0.534	0.719	0.740	0.469	-0.999	2.067
Race: Other	2.099	2.603	0.810	0.433	-3.449	7.648
Income [A]: Low	1.130	0.685	1.650	0.120	-0.329	2.590
Income: Middle	0.883	0.922	0.960	0.354	-1.084	2.849
Alcohol Use: Yes	0.534	0.719	0.740	0.469	-0.998	2.066
Drug Use: Yes	-0.290	1.026	-0.280	0.782	-2.476	1.897
Cigarette Use: Yes	0.879	0.760	1.160	0.266	-0.741	2.499

- Model Fit: R^2= 0.1978, F-Value = 158.89, p-value = <.0001
- * Indicates statistical significance at an alpha level of .05.
- A: Gender reference group-"Female", Race reference group-"White", Income reference group-"high", Alcohol/Drug/Cigarette Use reference group- "No"

Table 5. The model found an insignificant p-value of 0. 602 at an alpha level of .05 for the adjusted association between depression and systolic blood pressure. The parameter estimate

for depression was -0.036 (95% Confidence Interval: -0.181, 0. 109). For every one unit increase in depression score, systolic blood pressure decreased by 0.036 mmHg after controlling for all other covariates. Being male increased systolic blood pressure by 5.382 mmHg compared to females after controlling for all other covariates. Being black increased systolic blood pressure by 5.328 mmHg compared to whites after controlling for all other covariates. The R^2 value showing the proportion of dependent variance explained by the model was 0.1978. Age, BMI, gender, and race were found to be statistically significant at an alpha level of .05 when testing for the effect of a variable being added to the model.

Table 6. Adjusted Association between Depression and Diastolic Blood Pressure

Parameter	Estimate	Std. Error	t-value	p-value	95% Confidence Interval	
Constant	59.559	1.769	33.670	<.0001*	55.789	63.329
Depression	0.037	0.066	0.570	0.577	-0.103	0.177
Age	0.100	0.022	4.520	0.0004*	0.053	0.148
BMI	0.191	0.045	4.260	0.001*	0.096	0.287
Gender [A]: Male	2.920	0.519	5.630	<.0001*	1.813	4.026
Race [A]: Asian	2.422	0.644	3.760	0.002*	1.049	3.796
Race: Black	1.625	0.830	1.960	0.069	-0.144	3.394
Race: Hispanic	-1.166	0.646	-1.810	0.091	-2.542	0.210
Race: Other	-0.745	0.927	-0.800	0.434	-2.721	1.231
Income [A]: Low	-1.394	0.515	-2.700	0.016*	-2.492	-0.295
Income: Middle	-0.750	0.626	-1.200	0.250	-2.085	0.585
Alcohol Use: Yes	0.467	0.603	0.780	0.450	-0.817	1.752
Drug Use: Yes	1.409	0.945	1.490	0.157	-0.604	3.422
Cigarette Use: Yes	-0.798	0.550	-1.450	0.167	-1.969	0.374

- Model Fit: R^2= 0.06155, F-Value = 92.59, p-value = <.0001
- ***** Indicates statistical significance at an alpha level of .05.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

Table 6. The model found an insignificant p-value of 0.577at an alpha level of .05 for the adjusted association between depression and diastolic blood pressure. The parameter estimate for depression was 0.037 (95% Confidence Interval: -0.103, 0.177). For every one unit increase in depression score, diastolic blood pressure increased by 0.037 mmHg after controlling for all

other covariates. Being male increased diastolic blood pressure by 2.920 mmHg compared to females after controlling for all other covariates. Being Asian increased diastolic blood pressure by 2.422 mmHg compared to whites after controlling for all other covariates. The R^2 value showing the proportion of dependent variance explained by the model was 0.06155. Age, BMI, gender, race, and income were found to be statistically significant at an alpha level of .05 when testing for the effect of a variable being added to the model.

4.2 Associations between Depression and Blood Pressure using Bayesian Statistics

Statistical analysis from Bayesian statistics methods was done using simple linear regressions and multiple linear regressions. Systolic and diastolic blood pressure were modeled separately. **Table 7** displays systolic blood pressure as the dependent variable and depression as the independent variable using weakly informative priors, while **table 9** uses informative priors from parameter estimates and variances of the NHANES 2013-14 sample. **Table 8** displays diastolic blood pressure as the dependent variable and depression as the independent variable, using weakly informative priors, while **table 10** uses informative priors from prior years data. **Table 11** shows the relationship between systolic blood pressure as the outcome and depression as the independent variable adjusted for the covariates age, BMI, gender, race, income, alcohol use, drug use, and cigarette use with weakly informative priors, while **table 13** uses informative priors from preceding years data. **Table 12** shows the relationship between diastolic blood pressure as the outcome and depression as the independent variable adjusted for the covariates age, BMI, gender, race, income, alcohol use, drug use, and cigarette use with weakly informative priors, while **table 14** uses informative priors from previous years data.

Table 7. Crude Association between Depression and Systolic Blood Pressure with Weakly Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	122.335	0.343	122.337	121.668	123.007	121.660	122.994
Depression	0.036	0.063	0.037	-0.087	0.159	-0.087	0.158

- Priors used: normal (0,10000)
- HPD: Highest Posterior Density.

Table 7. The model displays the association between depression and systolic blood pressure using weakly informative normal priors with a mean of 0 and a variance of 10000. The posterior mean obtained for depression was 0.036 with a median of 0.037. The 95% equal-tailed credible interval is between -0.087 and 0.159, so there is a 95% posterior probability the true effect for depression and its association with systolic blood pressure lies in this interval given the observed data.

Table 8. Crude Association between Depression and Diastolic Blood Pressure with Weakly Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	70.537	0.244	70.539	70.062	71.016	70.056	71.006
Depression	0.010	0.045	0.010	-0.078	0.097	-0.078	0.096

- Priors used: normal (0,10000)
- HPD: Highest Posterior Density.

Table 8. The model displays the association between depression and diastolic blood pressure using weakly informative normal priors with a mean of 0 and a variance of 10000. The posterior mean obtained for depression was 0.010 with a median of 0.010. The 95% equal-tailed credible interval is between -0.078 and 0.097, so there is a 95% posterior probability the true effect for depression and its association with diastolic blood pressure lies in this interval given the observed data.

Table 9. Crude Association between Depression and Systolic Blood Pressure with Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	121.360	0.261	121.361	120.852	121.872	120.854	121.873
Depression	0.119	0.049	0.120	0.024	0.216	0.025	0.217

- Priors used: constant- normal(119.484,0.197), depression- normal(0.038,0.007)
- HPD: Highest Posterior Density.

Table 9. The model displays the association between depression and systolic blood pressure using an informative normal prior with a mean of 0.038 and a variance of .007 for depression. The posterior mean obtained for depression was 0.119 with a median of 0.120. The 95% equal-tailed credible interval is between 0.024 and 0.216, so there is a 95% posterior probability the true effect for depression and its association with systolic blood pressure lies in this interval given the observed data.

Table 10. Crude Association between Depression and Diastolic Blood Pressure with Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	70.485	0.185	70.486	70.123	70.851	70.119	70.846
Depression	0.008	0.028	0.008	-0.047	0.064	-0.046	0.065

- Priors used: constant- normal (70.296, 0.129), depression- normal(-0.0004, 0.0014)
- HPD: Highest Posterior Density.

Table 10. The model displays the association between depression and diastolic blood pressure using an informative normal prior with a mean of -0.0004 and a variance of 0.0014 for depression. The posterior mean obtained for depression was 0.008 with a median of 0.008. The 95% equal-tailed credible interval is between -0.047 and 0.064, so there is a 95% posterior probability the true effect for depression and its association with diastolic blood pressure lies in this interval given the observed data.

Table 11. Adjusted Association between Depression and Systolic Blood Pressure with Weakly Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	87.032	1.353	87.025	84.398	89.701	84.368	89.662
Depression	-0.047	0.057	-0.047	-0.158	0.065	-0.152	0.069
Age	0.403	0.016	0.403	0.371	0.435	0.370	0.434
BMI	0.421	0.034	0.421	0.354	0.486	0.355	0.487
Gender [A]: Male	4.948	0.495	4.945	3.986	5.911	4.026	5.949
Race [A]: Other	2.124	1.260	2.124	-0.342	4.614	-0.292	4.642
Race: Hispanic	0.950	0.620	0.951	-0.262	2.178	-0.336	2.098
Race: Black	5.371	0.676	5.372	4.036	6.682	4.031	6.676
Race: Asian	1.112	0.890	1.117	-0.630	2.882	-0.579	2.922
Income [A]: Low	2.127	0.624	2.128	0.904	3.349	0.908	3.351
Income: Middle	1.524	0.623	1.527	0.301	2.751	0.288	2.732
Alcohol Use: Yes	0.118	0.569	0.112	-0.982	1.232	-0.969	1.239
Drug Use: Yes	0.445	0.689	0.454	-0.892	1.800	-0.911	1.770
Cigarette Use: Yes	0.642	0.554	0.647	-0.453	1.731	-0.415	1.760

- Priors used: normal (0,10000)
- HPD: Highest Posterior Density.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

Table 11. The model displays the association between depression and systolic blood pressure using weakly informative normal priors with a mean of 0 and a variance of 10000. The posterior mean obtained for depression was -0.047 with a median of -0.047. The 95% equal-tailed credible interval is between -0.158 and 0.065, so given the observed data, there is a 95% posterior probability the true effect for depression and its association with systolic blood pressure lies in this interval after taking into account covariates. Age, BMI, gender (male), race (Black), and income (low, middle) had positive associations with systolic blood pressure based on the credible intervals being above 0.

Table 12. Adjusted Association between Depression and Diastolic Blood Pressure with Weakly Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	56.428	1.055	56.423	54.374	58.509	54.350	58.479
Depression	0.026	0.044	0.026	-0.060	0.113	-0.056	0.117
Age	0.122	0.013	0.122	0.097	0.147	0.096	0.146
BMI	0.237	0.026	0.237	0.185	0.288	0.186	0.289
Gender ^{A}: Male	2.769	0.386	2.767	2.019	3.520	2.050	3.550
Race ^{A}: Other	0.696	0.983	0.696	-1.227	2.638	-1.188	2.660
Race: Hispanic	-1.656	0.483	-1.656	-2.602	-0.699	-2.660	-0.762
Race: Black	1.560	0.527	1.561	0.519	2.582	0.515	2.578
Race: Asian	2.976	0.694	2.980	1.618	4.357	1.658	4.388
Income ^{A}: Low	-1.197	0.486	-1.196	-2.150	-0.244	-2.147	-0.242
Income: Middle	-0.174	0.486	-0.171	-1.128	0.784	-1.137	0.768
Alcohol Use: Yes	1.179	0.443	1.174	0.321	2.048	0.330	2.052
Drug Use: Yes	1.051	0.537	1.058	0.009	2.108	-0.006	2.084
Cigarette Use: Yes	-0.487	0.432	-0.483	-1.341	0.363	-1.311	0.385

- Priors used: normal (0,10000)
- HPD: Highest Posterior Density.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

Table 12. The model displays the association between depression and diastolic blood pressure using weakly informative normal priors with a mean of 0 and a variance of 10000. The posterior mean obtained for depression was 0.026 with a median of 0.026. The 95% equal-tailed credible interval is between -0.060 and 0.113, so given the observed data, there is a 95% posterior probability the true effect for depression and its association with diastolic blood pressure lies in this interval after taking into account covariates. Age, BMI, gender (male), race (Black, Asian), alcohol use, and drug use had positive associations with diastolic blood pressure based on the credible intervals lying above 0. Hispanic and low income was negatively associated with diastolic blood pressure based on the credible intervals being below 0.

Table 13. Adjusted Association between Depression and Systolic Blood Pressure with Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	86.787	0.763	86.775	85.313	88.317	85.314	88.317
Depression	-0.043	0.047	-0.044	-0.136	0.048	-0.137	0.046
Age	0.385	0.012	0.385	0.361	0.409	0.361	0.408
BMI	0.455	0.022	0.455	0.413	0.497	0.414	0.498
Gender ^{A}: Male	5.118	0.375	5.115	4.397	5.852	4.397	5.851
Race ^{A}: Other	1.850	0.901	1.856	0.066	3.618	0.089	3.635
Race: Hispanic	0.759	0.363	0.758	0.055	1.476	0.060	1.479
Race: Black	5.422	0.439	5.423	4.561	6.280	4.557	6.273
Race: Asian	1.565	0.585	1.562	0.422	2.716	0.419	2.712
Income ^{A}: Low	1.835	0.475	1.839	0.902	2.765	0.890	2.749
Income: Middle	1.091	0.394	1.093	0.316	1.858	0.318	1.860
Alcohol Use: Yes	0.280	0.391	0.279	-0.492	1.044	-0.485	1.047
Drug Use: Yes	0.157	0.491	0.159	-0.803	1.125	-0.810	1.114
Cigarette Use: Yes	0.857	0.406	0.857	0.060	1.648	0.074	1.658

- Priors Used See Appendix A (estimate, variance)
- HPD: Highest Posterior Density.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

Table 13. The model displays the association between depression and systolic blood pressure using an informative normal prior with a mean of -0.0518 and a variance of 0.0076 for depression. The posterior mean obtained for depression was -0.043 with a median of -0.044. The 95% equal-tailed credible interval is between -0.136 and 0.048, so given the observed data, there is a 95% posterior probability the true effect for depression and its association with systolic blood pressure lies in this interval after taking into account covariates. Age, BMI, gender (male), race (other, Hispanic, Black, Asian), income (low, middle), and cigarette use had positive associations with systolic blood pressure based on the credible intervals lying above 0.

Table 14. Adjusted Association between Depression and Diastolic Blood Pressure with Informative Priors							
Parameter	Mean	Std. Dev	Median	Equal-Tailed 95% Credible Interval		HPD 95% Cred. Interval	
Constant	56.326	0.711	56.318	54.939	57.746	54.939	57.743
Depression	0.010	0.028	0.010	-0.044	0.065	-0.043	0.066
Age	0.129	0.010	0.129	0.109	0.148	0.109	0.148
BMI	0.249	0.020	0.249	0.210	0.288	0.209	0.286
Gender [A]: Male	2.533	0.239	2.531	2.074	3.007	2.064	2.993
Race [A]: Other	0.294	0.804	0.301	-1.300	1.871	-1.256	1.908
Race: Hispanic	-1.886	0.366	-1.889	-2.597	-1.166	-2.582	-1.156
Race: Black	0.980	0.399	0.982	0.194	1.751	0.186	1.738
Race: Asian	2.261	0.379	2.259	1.521	3.010	1.527	3.015
Income [A]: Low	-0.885	0.363	-0.882	-1.600	-0.178	-1.602	-0.183
Income: Middle	-0.051	0.331	-0.049	-0.704	0.597	-0.720	0.575
Alcohol Use: Yes	1.070	0.306	1.070	0.467	1.665	0.459	1.652
Drug Use: Yes	1.287	0.425	1.288	0.453	2.124	0.458	2.127
Cigarette Use: Yes	-1.057	0.328	-1.057	-1.697	-0.416	-1.704	-0.428

- Priors Used See Appendix B (estimate, variance)
- HPD: Highest Posterior Density.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

Table 14. The model displays the association between depression and diastolic blood pressure using an informative normal prior with a mean of 0.0011 and a variance of 0.0013 for depression. The posterior mean obtained for depression was 0.010 with a median of 0.010. The 95% equal-tailed credible interval is between -0.044 and 0.065, so given the observed data, there is a 95% posterior probability the true effect for depression and its association with diastolic blood pressure lies in this interval after taking into account covariates. Age, BMI, gender (male), race (Black, Asian), alcohol use, and drug use had positive associations with diastolic blood pressure based on the credible intervals lying above 0. Hispanic, low income and cigarette use was negatively associated with diastolic blood pressure based on the credible intervals being below 0.

Chapter 5

DISCUSSION

5.1 Discussion of Results

The crude associations between systolic blood pressure and depression using frequentist methods, Bayesian weakly informative priors, and informative priors all yielded results marginally conflicted for each methodology. The frequentist and Bayesian nonnormative prior produced very similar results with both parameter estimates, and confidence/credible intervals leading to very similar conclusions about the crude association between depression and systolic blood pressure. The parameter estimate from the frequentist method was 0.026 and the Bayesian weakly informative method parameter was a mere 0.010 higher. Both the confidence interval and credible interval for the parameter estimates included 0, thus an increase in depression score may not have an effect on systolic blood pressure. However, the informative prior for the crude association resulted in a parameter of 0.119, and credible intervals greater than 0. The different results provide insight into nonnormative priors resulting in parameters similar to those found in frequentist statistics methods, while informative priors can result in different estimates. There may be a positive association with depression and systolic blood pressure. Although, if an individual had a maximum depression score of 27, systolic blood pressure would increase by 3.21 mmHg (27*0.119) without adjusting for any covariates. Though there may be statistical significance, there is a lack of clinical significance since systolic blood pressure increases by merely 3.21 mmHg with the worst possible depression severity score. The positive association is comparable to the results found in the study done by Ginty et al. (2013), where each unit in depression severity increased the odds of being hypertensive by 19% (Ginty et al., 2013). The crude association between depression and diastolic blood pressure resulted in the same conclusion for all three methods for estimating the parameter. All three parameters were close to 0, and all confidence and credible intervals included 0 between both the upper and lower bound intervals. Thus, based on the data and analysis there is no crude association between depression and diastolic blood pressure. Using an informative prior provided no additional benefit in finding an association.

The adjusted association between depression and systolic blood pressure using frequentist statistics, Bayesian weakly informative priors, and informative priors all yielded similar results for parameter estimates and conclusion derived from confidence and credible intervals. Parameter estimates for depression ranged from -0.047 to -0.036. All confidence and credible intervals contained 0 between the lower and upper bound estimates. Though all parameter estimates are negative, the intervals suggest there was no adjusted association between depression and systolic blood pressure. Age, BMI, being male, or being black all had positive associations with systolic blood pressure using all three statistical methods. This suggests that the effect is strong in its association with systolic blood pressure. The Bayesian weakly informative and informative models also found being low income or being middle income to be positively associated with systolic blood pressure. The Bayesian informative priors found Asian, Hispanic, other race and cigarette use to be positively associated along with the aforementioned variables. Assessment of associations was based on credible intervals and confidence intervals. It was expected for the weakly informative priors to yield similar results as those found in the frequentist methods, thus it was surprising to find that the weakly informative priors yielded more positive associations with systolic blood pressure than the frequentist methods. The different conclusions found in the positive associations between the Bayesian methods and the frequentist method may be due to the Bayesian method not applying sample weights to the analysis. For example, Hispanics make up 31.9% of the sample, but in the weighted sample the group only makes up for 15.6% of the sample. The weighted income category sample also differs from the observational sample. This could explain why more positive associations for variables are not seen in the frequentist method, and how weighted sampling effects the positive associations derived from the results.

The adjusted association between depression and diastolic blood pressure using frequentist statistics, Bayesian weakly informative priors, and informative priors all yielded similar results for parameter estimates and conclusion derived from confidence and credible intervals. The parameter estimates ranged from 0.010 to 0.037. All confidence and credible intervals contained 0 between the lower and upper bound estimates. Though all parameter estimates are positive, the intervals suggest there was no adjusted association between depression and diastolic blood pressure. Age, BMI, being male, or being Asian all had positive associations with diastolic blood pressure using all three statistical methods. Age, BMI, and being male have consistent findings from those found in the association of depression with systolic blood pressure. Having low income compared to high income was found to be negatively associated with diastolic blood pressure in all three statistical methods. Being black was found to be positively associated with diastolic blood pressure while being Hispanic was found to be negatively associated with diastolic blood pressure compared to whites in both the Bayesian weakly informative and informative models. Alcohol use and drug use were found to be positively associated with diastolic blood pressure in both models as well. The Bayesian informative model found smoking to be negatively associated with diastolic blood pressure. Again, it was expected that the frequentist model and the Bayesian weakly informative model would have similar results. However, most likely due to weights not being part of the Bayesian models, more variables were associated with diastolic blood pressure in the Bayesian weakly informative model than the frequentist model. All equal tailed and highest posterior density credible intervals resulted in the same conclusion of the parameters' association with blood pressure, except for drug use as a predictor for diastolic blood pressure using a weakly informative prior.

All explanatory variables were found to be associated with either systolic blood pressure or diastolic blood pressure in at least one of the models. This reaffirms the results of prior studies finding depression, age, BMI, gender, race, income, alcohol use, drug use, and cigarette use to be associated with blood pressure or hypertension. However, with regards to the direct linear relationship between depression and blood pressure, given the results of this study there does not seem to be a linear relationship between the two health outcomes. Only one model was able to find a linear association between depression and blood pressure. Though the association was statistically significant, there was no clinical significance in the effect. Though previous studies have found an association with depression and blood pressure, most have only done so through categorizing either blood pressure, depression, or both. The study conducted by Roane et al. (2017) failed to find an association between depression and systolic blood pressure or diastolic blood pressure, which is comparable to the results of the adjusted models used in this study (Roane et al., 2017). This study stands apart by attempting to find the association between two continuous variables, rather than dichotomizing the two.

5.2 Limitations and Future Directions

One main issue with the Bayesian analysis is that it does not apply the survey data weights, cluster, and strata which were applied to frequentist methods analysis. This issue would rationalize why some results varied between the frequentist methods and the weakly informative prior models. Since NHANES is a nationally representative survey data set, but the survey weights were not applied in the Bayesian models, the results from the Bayesian analysis may not be representative of the United States. In all Bayesian models, trace plots were used to assess convergence in obtaining the posterior mean for each parameter. All models parameters seemed to converge, thus resulting in accurate posterior distributions.

Another limitation of the study pertains to the depression variable. The depression questionnaire asked participants if they were feeling any of the depressive symptoms in the past two weeks. Participants may have experienced depression symptoms prior to the two weeks before the screener was administered. Another issue with the depression variable is that the variable is created using a depression screener, thus there is no clinical diagnosis for depression among the participants. Though the 9 item Patient Questionnaire to assess for depression is a valid assessment, it does not clinically diagnose patients with depression. The only way to do so would be through a professional.

Possible future directions to assess depression and blood pressure would be to categorize depression in terms of severity specified by the PHQ-9. Most studies dichotomize depression into a binary variable. However, depression has levels of severity: minimal, mild, moderate, moderately severe, and severe depression. Keeping depression as a continuous variable measures the level severity of depression, but placing the scores into bins could also capture the level of severity of depression and better find an association with blood pressure. Systolic blood pressure and diastolic blood pressure could also be modeled together as one outcome through multivariate regression modeling. Though there are many possible ways of finding an association between depression and blood pressure, it is important for the associations to be made by taking into account the levels of severity for each variable, rather than simply dichotomizing continuous variables into a binary variable.

5.3 Conclusion

Though there was an association found between depression and systolic blood pressure, the measure of effect did not have clinical significance. Though other studies found associations of depression and blood pressure, the association still needs to be explored in more depth with an emphasis on how the severity of depression is treated. This study also reinforces the association of factors such as age, BMI, gender, and race being associated with blood pressure. More attention should be paid to those at greater risk for the disease burden associated with high blood pressure.

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APPENDIX A

Adjusted Association between Depression and Systolic Blood Pressure with NHANES 2013-2014					
Parameter	Estimate	Std. Error	Variance	t-value	p-value
Constant	86.393	1.168	1.363	74.000	<.0001*
Depression	-0.052	0.087	0.008	-0.590	0.562
Age	0.349	0.022	0.0005	15.860	<.0001*
BMI	0.469	0.034	0.001	13.830	<.0001*
Gender [A]: Male	5.366	0.596	0.355	9.000	<.0001*
Race [A]: Asian	2.017	0.845	0.715	2.390	0.031*
Race: Black	5.526	0.631	0.398	8.750	<.0001*
Race: Hispanic	0.455	0.479	0.229	0.950	0.357
Race: Other	1.704	1.326	1.758	1.290	0.218
Income [A]: Low	1.235	0.919	0.845	1.340	0.199
Income: Middle	0.810	0.536	0.287	1.510	0.151
Alcohol Use: Yes	0.461	0.577	0.333	0.800	0.438
Drug Use: Yes	-0.107	0.724	0.524	-0.150	0.885
Cigarette Use: Yes	0.896	0.649	0.421	1.380	0.187

- Indicates statistical significance at an alpha level of .05.
- A: Gender reference group-“Female”, Race reference group-“White”, Income reference group-“high”, Alcohol/Drug/Cigarette Use reference group- “No”

APPENDIX B

Adjusted Association between Depression and Diastolic Blood Pressure with NHANES 2013-2014					
Parameter	Estimate	Std. Error	Variance	t-value	p-value
Constant	55.742	1.307	1.708	42.650	<.0001*
Depression	0.001	0.036	0.001	0.030	0.977
Age	0.137	0.018	0.0003	7.410	<.0001*
BMI	0.274	0.038	0.001	7.170	<.0001*
Gender [A]: Male	2.268	0.308	0.095	7.360	<.0001*
Race [A]: Asian	1.948	0.466	0.218	4.180	0.001*
Race: Black	0.164	0.689	0.474	0.240	0.816
Race: Hispanic	-1.358	0.666	0.443	-2.040	0.059
Race: Other	-0.193	1.455	2.116	-0.130	0.896
Income [A]: Low	-0.387	0.637	0.406	-0.610	0.553
Income: Middle	-0.189	0.484	0.235	-0.390	0.702
Alcohol Use: Yes	0.689	0.448	0.201	1.540	0.145
Drug Use: Yes	1.242	0.733	0.537	1.700	0.111
Cigarette Use: Yes	-2.064	0.550	0.302	-3.750	0.002*

- Indicates statistical significance at an alpha level of .05.
- A: Gender reference group-"Female", Race reference group-"White", Income reference group-"high", Alcohol/Drug/Cigarette Use reference group- "No"